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SMALL HOSE STREAMS FOR FIGHTING MINE FIRES

BY

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SMALL HOSE STREAMS FOR FIGHTING MINE FIRES

By L. D. TRACY AND R. W. HENDRICKS

INTRODUCTION

Largely as a result of the Cherry mine fire in Illinois, November 13, 1909, which killed 259 men, the Illinois Mining Commission and the Bureau of Mines, Department of the Interior, made informal tests to ascertain the most suitable hydrant pressures and sizes of hose and nozzles for use as a "first aid" in fighting underground fires. The tests of the commission were made at the Chicago laboratory of the National Board of Fire Underwriters in 1910; those of the bureau were made at its experimental mine near Bruceton, Pa., in 1912. The results of these informal tests were incorporated in Technical Paper 24 of the Bureau of Mines. Since these tests were made it has seemed desirable to obtain further information on certain questions that have arisen and to check, if possible, the results published in that paper.

In consequence the director of the Bureau of Mines made arrangements with the Chicago laboratory of the National Board of Fire Underwriters for a series of tests to supplement the information obtained in the former experiments. These tests were made with the cooperation and assistance of the hydraulic engineering staff of the Underwriters' Laboratories.

ACKNOWLEDGMENTS

The writers acknowledge the cordial cooperation of the officials of the Underwriters' Laboratories, who placed men and apparatus at their disposal. Especially do they express their appreciation for the advice and assistance of Messrs. A. W. Claussen and Elmer Canman, assistant engineers, and Bryan A. Remick, laboratory assistant, all members of the staff of the Underwriters' Laboratories, who did much of the physical part of the testing.

OBJECT OF TESTS

The main object of these tests was to ascertain the equipment and pressures with which a man of average weight and strength, without assistance, could fight a mine fire most effectively. An ordinary miner may be unfamiliar with the direction and reaction of the forces developed when water under high pressure is suddenly turned into a hose line, he may be in darkness, he may have to walk or crawl over rough places, and he may be nervous or highly excited. All these possibilities must be taken into consideration.

There is always the chance that the hose line will warp and the sudden reaction will knock the man off his feet, or under an extremely high pressure the nozzle may get away from him and perhaps stun him if it hits him. That this danger is not imaginary is shown by the rule in every well-trained fire department that there shall always be at least two men to handle a play-pipe, and three men on roofs and other places where footing is insecure. Yet the average nozzle pressure of an ordinary fire stream is probably not as great as some of the pressures obtained in these tests.

The scope of the tests included the probable movements of a man endeavoring to turn a stream of water on a mine fire. He might unreel 50 feet of hose; then, with the nozzle in one hand, open the hydrant valve to its full width with the other, and having done this advance toward the fire dragging the slack of the hose after him.

Furthermore, as one man, single handed, may have to fight a fire for some time the apparatus and pressures should be such that his muscles would not become numb from the vibrations of the hose; nor should he become too fatigued by reason of the exertion necessary under the conditions that would prevail in the average mine

The points mentioned above were kept in mind in making the series of tests to determine the ability of one man to manipulate a hose line at different pressures. The tests comprised stretching a line of 50 feet of 1½-inch hose with different warps [1] and bends and using hydrant pressures ranging from 30 pounds to 150 pounds per square inch. The nozzles were all cone-shaped and ranged from seven-sixteenths inch to seven-eighths inch in diameter. A few similar tests were made with 2½-inch hose.

EQUIPMENT USED AND CONDUCT OF TESTS

Those making the tests felt that equipment of the kind tested should be designed for quenching a fire in its incipient stage rather than for fighting a fire after it has gained headway. When a fire starts, any saving of time is important, and an equipment that can be quickly assembled and made ready will be the most satisfactory, provided. of course, that it delivers an effective stream of water.

The tests were conducted in the hydraulic laboratory, which is well equipped with suitable apparatus. Pressures up to 200 pounds per square inch were obtained at the hydrant by means of tanks with compressed-air cushions. The water from the city water mains was admitted to a 25,000-gallon reservoir in the laboratory; from this reservoir it was pumped by an electrically driven centrifugal fire pump and an electrically driven screw pump into two riveted steel tanks having a capacity of 4,000 gallons, and so designed that they would stand a working pressure of 200 pounds per square inch with a safety factor of 6. Each pressure tank was connected to an electrically driven air compressor which was used to charge the tanks with air at the start of the tests. As water was drawn from the tanks it was replenished by the centrifugal pump; for the higher pressures the centrifugal pump and screw pump were connected in series, the former acting as a booster.

---

[1] The word "warp" is used instead of the more commonly used term "kink" because the latter signifies a sharp angular bend, whereas in these tests the bend was smooth, a warp—the shape assumed by the hose under pressure.

In those tests for which a hydrant pressure of 90 pounds per square inch was required, the tank pressure generally stood at 125 to 130 pounds per square inch. When higher hydrant pressures were desired, the tank pressure was increased to 180 or 200 pounds.

A 6-inch wrought-iron pipe led from the tank to a control valve to which was connected a 2½-inch rubber-lined cotton hose terminating in a piezometer of the size of the hose under test—a 1½-inch piezometer for a 1½-inch hose and a 2½-inch piezometer for a 2½-inch hose. As these piezometers were some distance from the control valve, a small line of patrol rubber hose about one-half inch in diameter led from them to the control valve and was connected there with a pressure gauge in order that the man operating the control valve could readily adjust the flow of water to the desired hydrant pressure (Plate I).

The arrangement described was necessary because the controlling valve at the end of the 6-inch 'wrought-iron line from the pressure tank was about in the longitudinal center of the laboratory. It was impossible to connect to this valve the 50 feet of hose used in the test, stretch the hose straight to cut friction loss to a minimum, and have enough room in front for the stream of water from the nozzle; but by attaching a 2½-inch hose line to the valve and leading it to the extreme end of the laboratory, there was room enough for a 50-foot stretch of hose and the longest stream of water that was obtained; moreover, as the piezometers were placed at the end of the 2½-inch hose, the pressure measurements were as accurate as if the 50-foot length of hose had been connected directly to the controlling valve.

Plate I shows the 2½-inch hose leading to the end of the laboratory, where it was connected with a piezometer and thence to the straight line of 1½-inch hose. In the background a man holds the support used to keep the nozzle 10 inches from the floor. At the right is the control valve with the gauge showing the pressure at the 1½-inch piezometer at the operator's left. The right-hand gauge indicated the pressure in the supply main.

HEIGHT OF STREAM

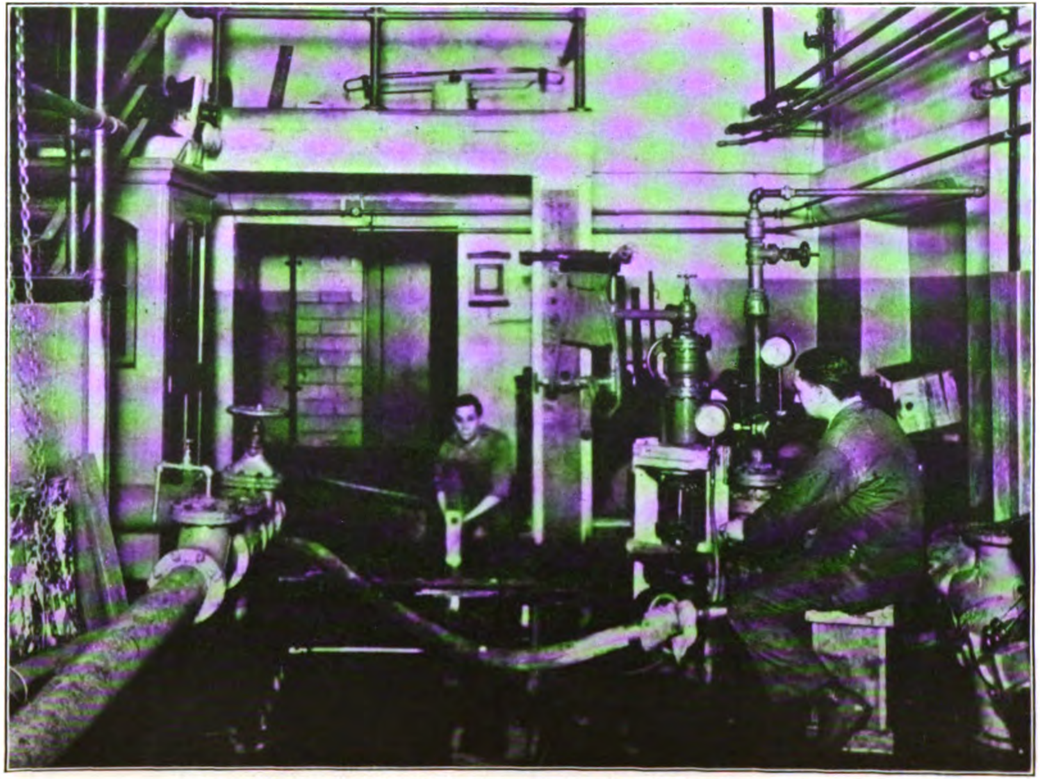
It had been decided that the extreme vertical distance from the floor to which the stream should rise from the nozzle, when held 10 inches from the floor, should be limited to 7½ feet, or about the height of an entry in an average mine. Several frames were made, each of two upright timbers, well braced and connected by a cross bar, whose bottom was exactly 7½ feet from the floor. These frames were placed in line and were moved back and forth in order to ascertain the maximum trajectory of a stream that would at all times just pass under the cross bar.

A form for holding the nozzle exactly 10 inches from the floor (Pl. I) was permanently placed at the zero point. From this point at intervals of 5 feet numbered cross lines were painted on the floor with white lead (Pl. II). The odd feet and fractions were either estimated or were measured with a 5-foot rule.

EFFECT OF HYDRANT PRESSURES

During the tests to determine the length of the stream, one man operated the controlling valve and noted the reading of the pressure gauge, another manipulated the nozzle, another moved the wooden frames and directed the raising or lowering of the nozzle so that the stream would just pass under the cross bars, and a fourth observed and recorded the length of the stream.

Tables 1 and 2 contain data on the effect of different hydrant pressures on a man of average height and strength using 1½-inch and 2½-inch rubber-lined cotton hose fitted with nozzles of various sizes.



VIEW IN LABORATORY SHOWING HOSE, GAUGES, AND VALVES

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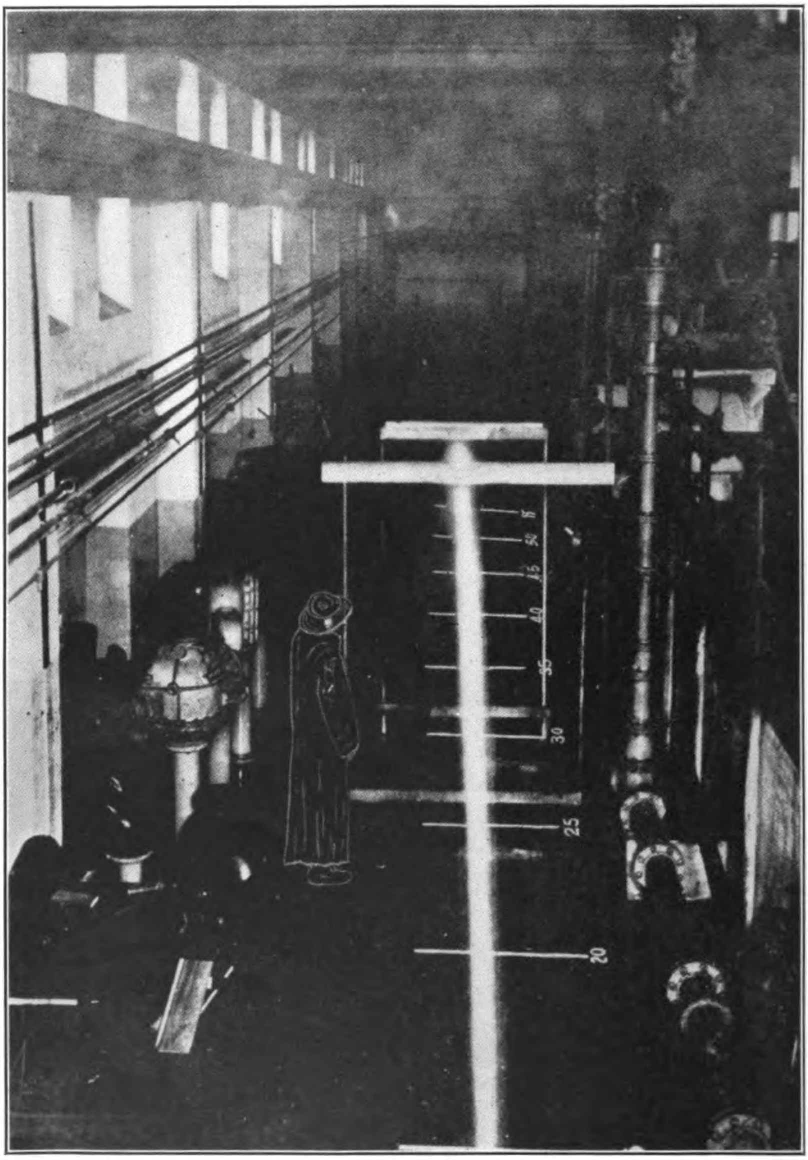

STREAM FROM A HOSE LINE PASSING UNDER THE FRAMES

TABLE 1.—*Data on tests with 1½-inch hose*

Hydrant pressure, pounds per square inch	Reaction of nozzle	Reaction of hose	Degree of control by one man	Remarks
Nozzle ⁷⁄₁₆ by 12 inches:				
30			Easy with one hand	Able to turn hydrant valve at will.
40			do	Difference slight.
55			Two hands needed or one hand with hose braced against body.	Use possible under adverse conditions.
70	Liable to escape		do	Do.
80	Escape highly probable if water in hose and pressure reach nozzle as soon as valve is opened.		Two hands needed; control with one hand doubtful.	With no water in hose and a quick-acting valve, a man might be able to open hydrant wide and grab nozzle with both hands before pressure became uncontrollable.
100	do	Tends to warp [a]	Difficult even with hose stretched in a straight line.	Man's full strength required to move with hose warped; [a] he can neither advance nor retreat.
125	Decided kick when pressure is turned on suddenly.	do	Hose can be handled if it does not warp. [a]	
150	do	do	Hose can be handled if man braces himself and keeps it in a straight line.	Strain and vibration of nozzle tend to numb muscles and are exhausting.
Nozzle ½ by 12 inches:				
40			Easy with one hand	Can easily turn hydrant valve with one hand.
55		Danger of hose unbalancing man should he trip or stumble.	More difficult	By pressing hose against body, a man could turn valve or move hose line.
70	May jerk loose if pressure comes on suddenly.	do	do	Same as above. Attempts to recover escaped hose might be dangerous. [b]
85	do	Tends to warp [a]	Very difficult	Danger point reached. Practicability doubtful where roof is low, as in a 4 or 5 foot coal bed.
100	Greater possibility of escape. If released for an instant, nozzle thrashes around dangerously.	Tends more to warp [a]	Still more difficult	Control impossible under ordinary mining conditions. Possibly one man could control hose laid in a straight line with no warp if he did not move around.
125	Decided kick if pressure comes on suddenly.	do	Both hands must be kept on nozzle.	Difficulty in moving if hose is warped.
150	Terrific kick. Fairly heavy man can barely manipulate nozzle.	Hose unmanageable when warped; man can not move with it. Escaped hose probably could not be recovered.	do	Danger of severe injury by nozzle of writhing hose in attempts to recover it.

---

[a] See footnote, page 2.

[b] Just what constitutes danger in handling a hose is largely a matter of opinion. Tests to ascertain how seriously a man might be injured before the action of the hose is considered dangerous are obviously impracticable. The statement here is based on experience and judgment rather than on any data from tests.

Original from UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

TABLE 1.—*Data on tests with $1^{1}/_{2}$-inch hose*—Continued

Hydrant pressure, pounds per square inch	Reaction of nozzle	Reaction of hose	Degree of control by one man	Remarks
Nozzle ¾ by 8 inches:				
40			Easy with both hands.	One hand can manage hose a little while, but quickly tires.
55		Would unbalance man should he stumble even when holding with both hands.	Possibly with both hands.	Only by holding nozzle against body could a man free one hand to turn valve.
70		Difficult to move back and forth.	Difficult with both hands.	Back pressure enough to lift and skid a man some distance if he moved backward.
80		Difficult to move under full pressure.	Impossible unless hose is laid straight and he can pick up nozzle after turning valve before full pressure reaches nozzle.	Not practicable in a low-vein coal mine.
100		Terrific thrashing about when escaped.	Limit of possible control. A man would soon become exhausted.	Should a man stumble, he would probably be struck and killed by nozzle.
125	Difficult to keep horizontal.	do	Only when hose line is straight.	When hose warps a second man is needed.
140 to 150	Upward vertical thrust strong enough to lift a man.	do	Can not always be controlled.	Man at nozzle was lifted, forced back, and caught by second man.

TABLE 2.—*Data on tests with $2\frac{1}{8}$-inch hose*

Hydrant pressure, pounds per square inch	Reaction of nozzle	Reaction of hose	Control by one man	Remarks
Nozzle $\frac{5}{8}$ by 8 inches:				
30		Weight and stiffness when full of water impede movement.	Yes	Could turn on valve and manage hose, but probably would have to lay hose straight first.
40 to 50		Weight and stiffness when full of water impede movement. Tends to kink.[a]	do	Retreat with hose difficult.
70		Holding nozzle to ground prevents vertical bend.	Difficult with hose held waist high.	
80		do	do	Difficulty increased.
100	Liable to jerk from hands.	Liable to unbalance man if he moves.	Almost impossible, especially if hose warps. A man of light weight would quickly tire.	Impossible for one man to fight fire at these high pressures with any size of nozzle in low-roofed mine.
125	Whole weight of man needed to prevent nozzle rising perpendicularly.	do	Probable, if hose is laid straight and nozzle held to ground.	Practicability doubtful in ordinary coal mines.
150	do	do	Very difficult by a man (weight 165 pounds) standing still.	Limit of safety. Attempts to recover escaped hose very dangerous.[b]
Standard underwriters' play-pipe with grip handles at butt end; $\frac{3}{4}$-inch nozzle:				
35 to 80		Tends to warp at 80 pounds pressure.	Easy	Taxes man's strength at 80 pounds. Hose laid straight just as unmanageable as when laid with a bend.
100		Warps; almost lifts man moving backward.	Difficult	Strain severe; could not be endured long.
125		Reaction backward and sidewise; very difficult to manage.	Very difficult	
145		do	do	Maximum pressure for control with long bend in hose.
150		do	Limit of ordinary man's strength.	
Nozzle $\frac{7}{8}$ by 15 inches:				
30		Kinks[a] easily when moved.	Easy	
40		do	Difficult when hose warps.	
55		With vertical bend would unbalance man retreating.	Hard for holder to keep footing.	
70		Right-angle bend forces man back and requires help of a second man.	Barely possible with straight hose.	

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[a] The word "kink" is used here because the hose assumes an angular shape with a crease in the fabric which completely stops the flow of water.

[b] Just what constitutes danger in handling a hose is largely a matter of opinion. The statements under "Remarks" in this table are based on experience and judgment rather than on any data from tests.

DISCUSSION OF RESULTS

The vibration of the hose and nozzle at pressures approximating 100 pounds is very noticeable and after any length of time tends to numb the muscles of the holder.

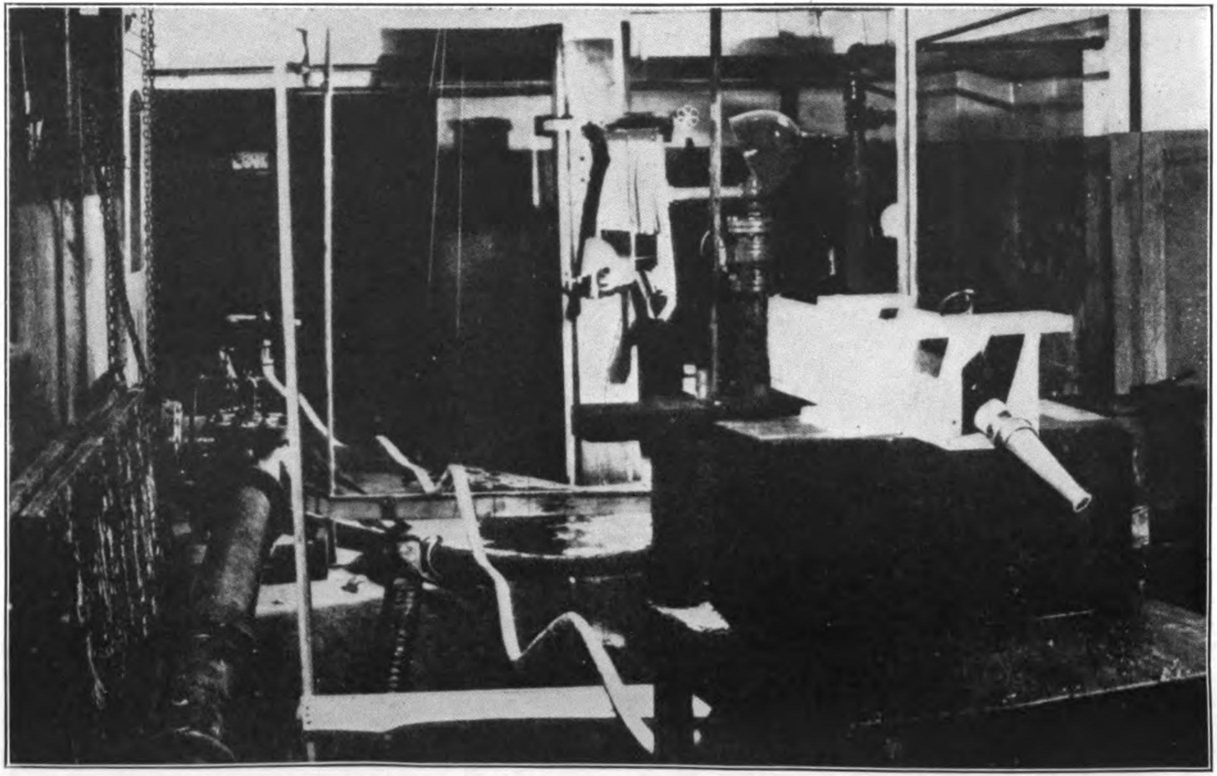
Although the strain of these heavy pressures is endurable for a short time, it will so fatigue a man that eventually he would have to give up the fight. With respect to controllable hydrant pressures, it is questionable whether the additional amount of water obtained by heavy pressures and a 2½-inch hose, but with the disadvantage of the extra weight and stiffness, is more desirable than less water with a lower hydrant pressure and a smaller hose that can be more easily handled and moved from place to place. Decision on this point must take into consideration the generally adverse conditions under which a mine fire is fought and the facts that one man must do all the work and that if he is injured the only chance of checking the fire has been destroyed.

REACTION PRESSURES

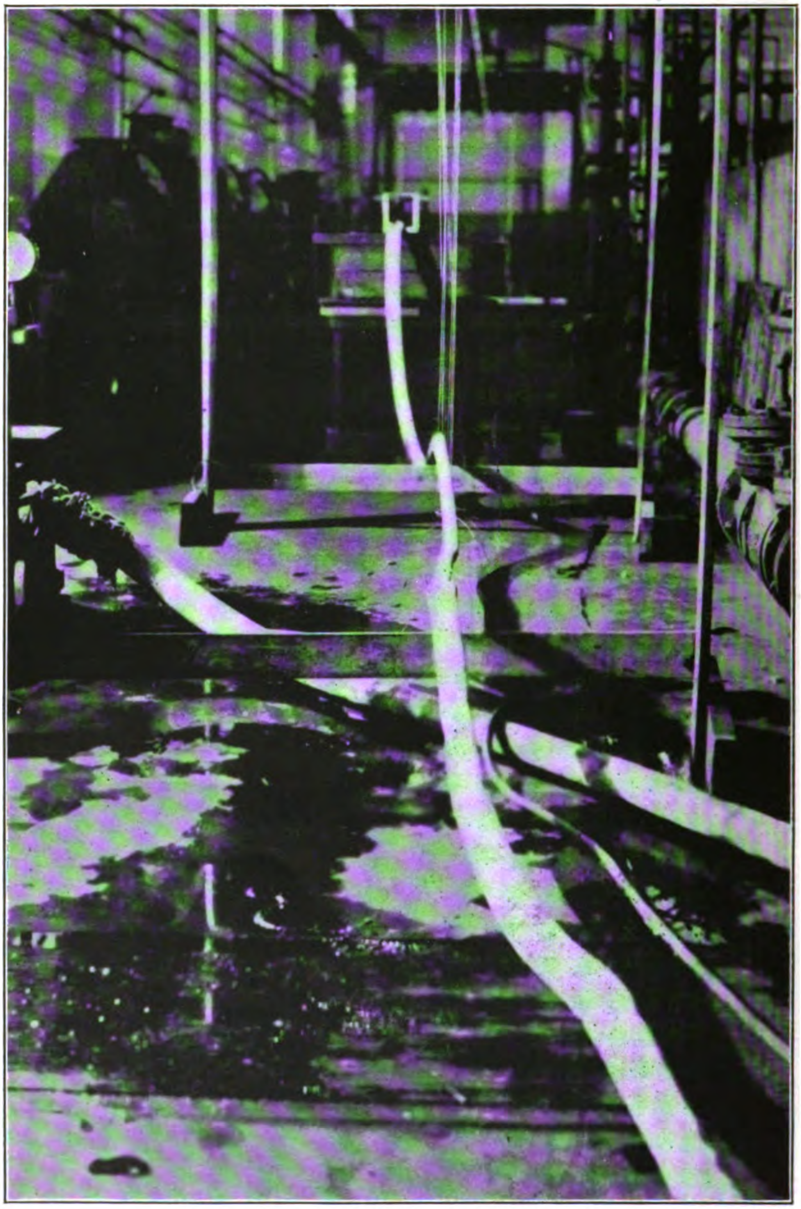
It seemed advantageous to supplement the foregoing tests with others, to obtain some fairly accurate data on the pressures a man would have to resist when handling a hose with different size nozzles and under different hydrant pressures.

A wooden trough about 4 inches wide, 6 inches deep, and 29 inches long was so placed that a hose nozzle could rest on the bottom, with the bends in the hose leading to it as similar as possible to those assumed when the nozzle was manipulated by one man. Strips were nailed across the top to prevent the nozzle from getting out of the trough. A spring balance was securely fastened to the front end of the box and was connected to the hose nozzle. (See Pl. III.) During a test the nozzle did not project beyond the front of the box.

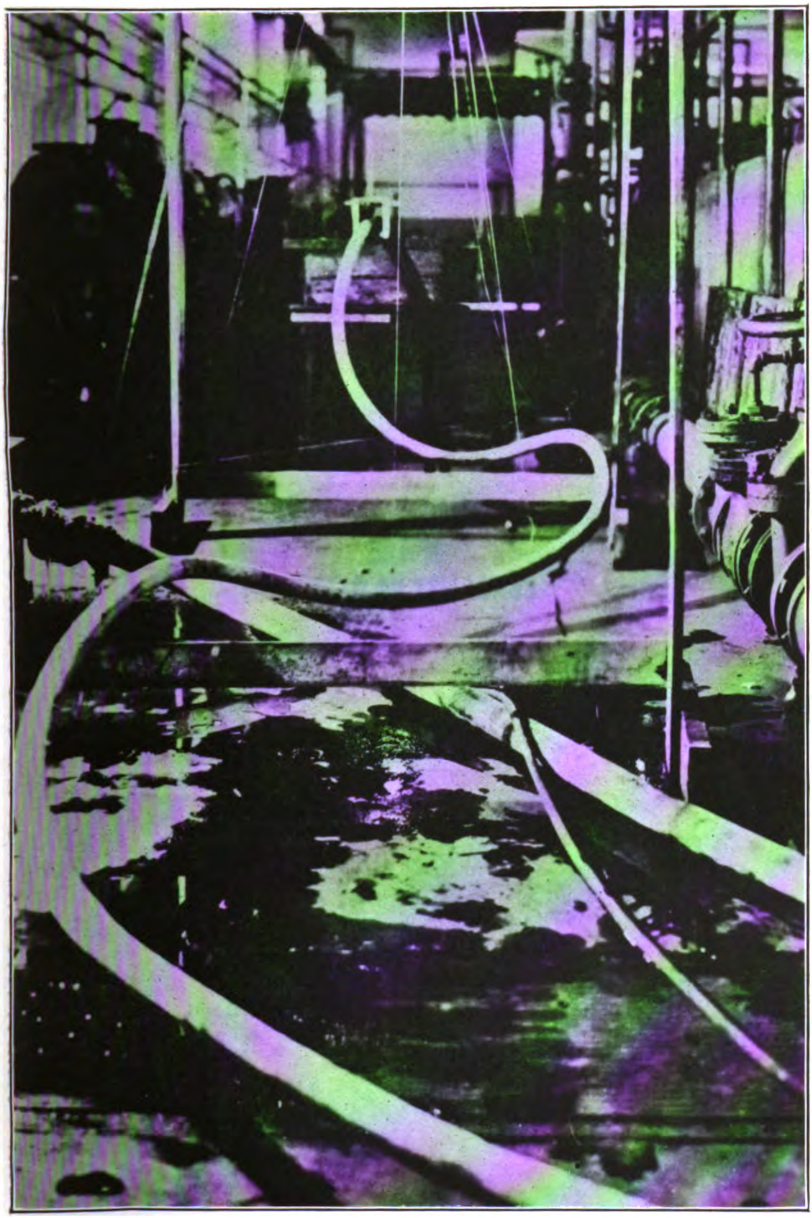
To avoid possible resistance due to the friction of the hose on the floor, the hose for about 30 feet back of the nozzle was suspended by cords as shown in Plate IV. The pressure was gradually turned on, and the readings of the spring balance and of the gauge giving the hydrant pressures were taken simultaneously. Plate V shows the position taken by the hose under pressure. Table 3 gives the results, in pounds, of a backward horizontal force due to the reaction of the nozzle.



GENERAL APPEARANCE OF HOSE LINE JUST BEFORE A TEST; DURING THE TEST THE NOZZLE DID NOT PROJECT BEYOND THE FRONT OF THE BOX



HOSE SUSPENDED BY CORDS BEFORE THE WATER IS TURNED ON



POSITION OF THE HOSE UNDER PRESSURE

TABLE 3.—*Reaction pressures, in pounds, of $1\frac{1}{2}$-inch hose with different sizes of nozzles*

Hydrant pressure	Nozzle reaction		
	First test	Second test	Third test
Nozzle, $\frac{7}{16}$ by 12 inches:			
50	12	13	14
60	14	12	
70	15	13	
80	17	14	18
90	19	16	
100	21	18	23
110	23	17	
120	25	18	
130	25	22	30
140	27	26	
150	30	27	33
Nozzle, $\frac{1}{2}$ by 12 inches:			
50	17	18	18
60	20	22	18
70	23	24	20
80	23	26	24
90	27	28	27
100	27	32	30
110	32	34	32
120	34	39	34
130	36	41	38
140	37	47	38
150	40	46	41
Nozzle, $\frac{3}{4}$ by 8 inches:			
50		24	
60	27	36	
70	35	43	
80	42	48	
90	47	52	
100	50	53	
110	58	58	
120	58	63	
130	65	68	
140	72	71	
150	80	77	

The weight of the hose and water and the lack of space made tests similar to the preceding impracticable with a 2½-inch line of hose.

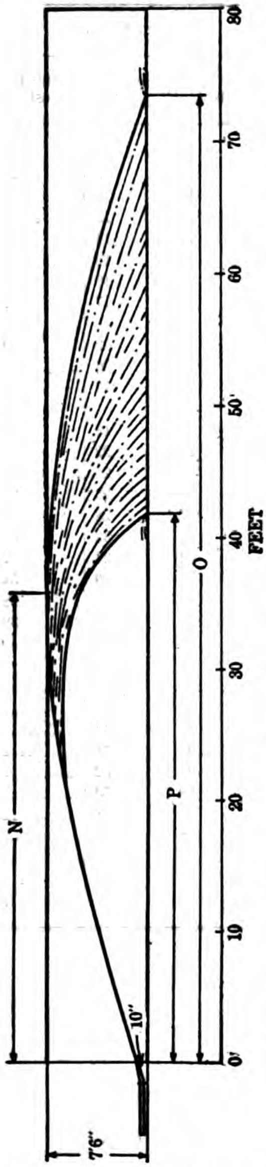


FIGURE 1.—Effective reach of fire streams with varying hydrant pressures and different sizes of nozzles in an entry 7½ feet high

Variations of a few pounds in the pressure noted during the tests may be accounted for by the pulsating action of the stream, which at times was very noticeable.

With the horizontal reaction at the nozzle there is a vertical upward pressure that seems to be quite as strong as the horizontal. An attempt was made to measure this reaction, but the directions of force were too complex for the apparatus available.

TRAJECTORY TESTS

TESTS WITH 1½-INCH HOSE

Table 4 and Figure 1 give the results of the tests to determine the maximum trajectories of hose streams where the height of the roof is 7½ feet. N in Figure 1 represents the horizontal distance from the nozzle at which a stream is tangent to the roof of an underground working 7½ feet high when the stream is at its maximum trajectory at a given pressure and the nozzle of given size is held 10 inches above the floor; O, the horizontal distance from the nozzle to the farthest point on the floor that was wet by the stream under the conditions of N; P, the horizontal distance from the nozzle to the nearest point wet by the stream under the conditions of N. The difference between O and P thus measures the extreme spread of the stream where it strikes the floor.

In the determination of the distance P, the part of the floor wet by a few scattering drops was not taken into account but the measurement was taken to the nearest point where a considerable amount of water was falling.

TABLE 4.—*Maximum trajectories with a height of 7½ feet; 1½-inch cotton rubber-lined hose and different sizes of nozzles*

Hydrant pressure, pounds per square inch	Nozzle pressure, pounds per square inch	Gallons thrown per minute	N		P		O		Condition of stream
			Ft.	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	
Nozzle, 7/16 by 12 inches:									
10	9.5	15.0	15	2	27	0	31	0	
15	14.0	18.5	22	6	35	0	40	0	
20	19.0	21.0	26	6	38	0	48	0	
25	24.0	23.5	31	0	40	0	55	0	
30	29.0	26.0	33	6	40	0	58	0	
35	34.0	27.5	34	6	40	0	61	0	
40	39.0	29.0	36	0	40	0	62	0	
45	44.0	30.5	36	0	35	0	65	0	
50	48.0	32.3	37	0	30	0	65	0	Shattered; has no body.
60	58.0	35.7	37	0	25	0	67	0	
Nozzle, ½ by 12 inches:									
10	9.0	21.5	17	0	27	0	35	0	
15	14.0	26.5	21	6	40	0	44	6	
20	12.5	31.0	26	0	44	0	52	0	
25	23.0	34.0	29	6	44	0	57	0	
30	28.0	37.5	32	6	40	0	62	6	
35	32.0	41.0	35	6	40	0	66	0	
40	37.0	43.5	36	0	40	0	69	0	
45	42.0	46.0	37	0	40	0	72	6	
50	46.0	48.0	38	6	20 to 40	0 0	73	0	Badly broken.
60	55.5	53.0	38	6	20 to 40	0 0	75	0	Has no body.
Nozzle, ⅝ by 8 inches:									
10	8.5	32.0	18	0	28	0	36	0	
15	12.5	41.0	22	0	30	0	46	0	
20	16.5	46.0	26	0	35	0	54	0	
25	20.5	52.0	31	0	30	0	58	0	
30	25.0	57.0	35	0	30	0	67	0	
35	29.0	61.0	37	0	30	0	70	0	
40	33.0	66.0	38	0	30	0	74	0	
45	37.0	70.0	38	0	20 to 30	0 0	76	0	Begins to break.
50	40.5	73.0	41	0	--------		77	6	Badly broken.
60	48.5	80.0	43	0	--------		82	0	Has no body.
Nozzle, ¾ by 8 inches:									
10	8.0	45.0	13	6	25	0	28	6	
15	11.0	58.0	19	0	34	0	39	0	
20	13.5	65.0	23	0	35	0	47	6	
25	16.5	73.0	26	0	42	6	52	6	
30	19.5	79.0	29	0	45	0	57	6	
35	22.5	86.0	31	6	40	0	63	0	Has much spray.
40	25.5	91.0	35	0	40	0	67	6	
45	28.5	96.0	36	6	37	0	72	6	
50	31.5	100.0	38	0	30	0	75	0	Only fairly heavy at extreme end.
60	38.0	110.0	40		20 to 33	0 0	81	0	Begins to break badly.
70	44.5	119.0	41	0	--------		77	6	Broken so badly as to be ineffective.

TESTS WITH 2½-INCH HOSE

Data for a 2½-inch hose are not as complete as those for the 1½-inch hose but are interesting chiefly as a basis for comparison.

A Standard Underwriters' play-pipe was fitted with a three-fourths inch smooth-bore nozzle and attached to 50 feet of 2½-inch cotton rubber-lined hose. Unlike the tests with 1½-inch hose the stream was not directed under the 7½-foot frame.

At pressures of 35 to 50 pounds the body of the stream fell 65 to 70 feet from the nozzle. When the pressure was increased to 80 pounds the distance from the nozzle to the point on the floor wet by the main body of the stream was 100 to 110 feet. At 100 pounds pressure and over there was much mist and spray, but not enough to affect the carrying power of the stream or to impair its fire-fighting efficiency.

The length of the stream could not be determined accurately at these pressures because of the limitation due to the length of the building.

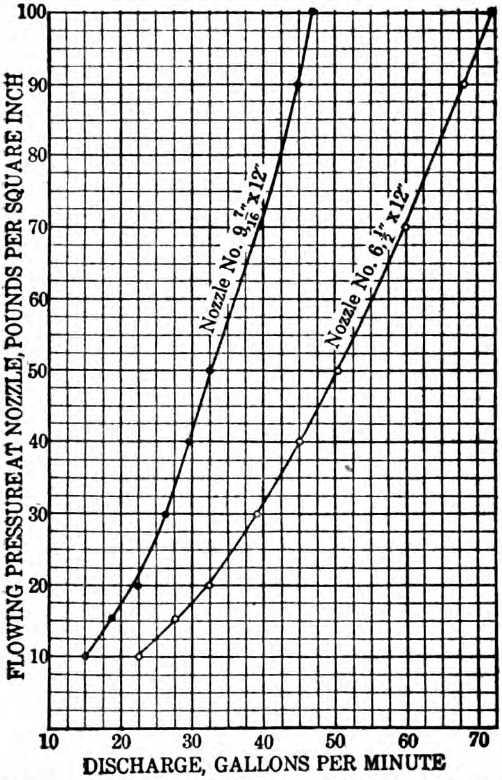


FIGURE 2.—Curves showing results of calibration tests of 7/16 by 12 inch and ½ by 12 inch nozzles

The tests show that a greater trajectory with a more solid stream can be obtained with a 2½-inch hose than with a 1½-inch hose.

CALIBRATION OF NOZZLES

Figures 2 and 3 are charts showing the results of the calibration tests of four sizes of nozzles.

The curves in Figures 2 and 3 show the discharge, in gallons per minute, as plotted against the flowing pressure at the nozzle, in pounds per square inch. The pressure at the nozzle was obtained by connecting a calibrated gauge to a 1½-inch piezometer to which the nozzle was attached. The discharge from the nozzles was directed into a calibrated measuring tank and the time was determined with a stop watch.

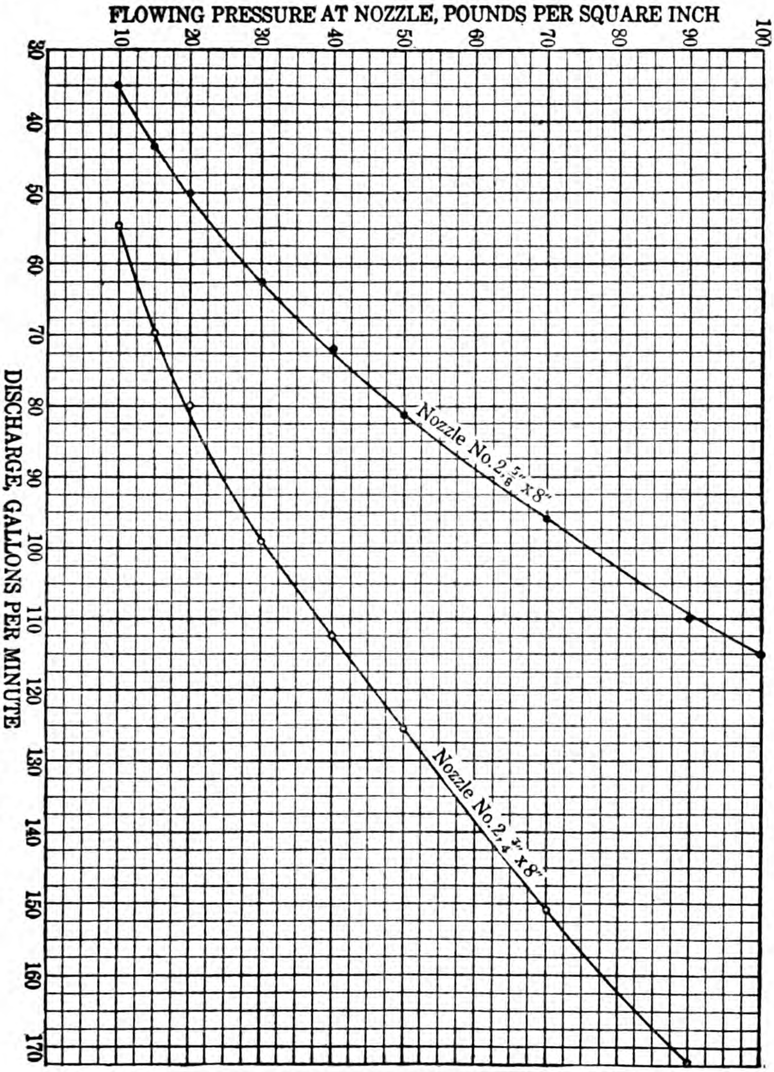


FIGURE 3.—Curves showing results of calibration tests of ⅝ by 8 inch and ¾ by 8 inch nozzles

FRICTION-LOSS TESTS

Figure 4 shows the results of a friction-loss test of the 50-foot length of cotton rubber-lined 1½-inch hose used and the loss of head, in pounds per square inch, plotted against rate of flow, in gallons per minute.

Figure 5 in which nozzle pressure is plotted against hydrant pressure, gives the loss of head by friction for two different nozzles.

The five-eighths-inch nozzle used was in reality a three-fourths-inch nozzle into which a brass sleeve with an inside diameter of five-eighths inch was pressed. This sleeve was smoothly finished and the entrance at the inner end was chamfered to eliminate any abrupt change in the waterway.

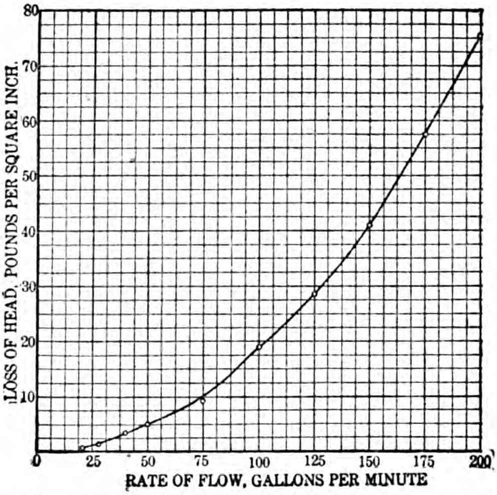


FIGURE 4.—Friction loss per 50 feet of cotton rubber-lined 1½-inch hose

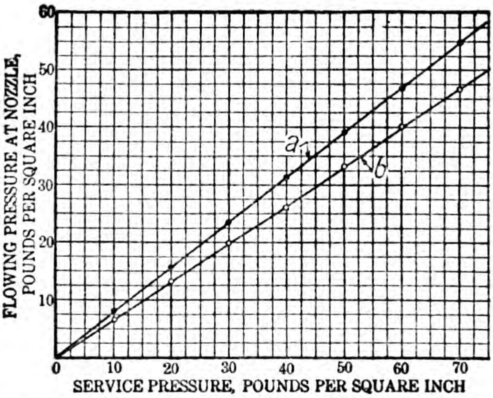


FIGURE 5.—Curves showing the relation between hydrant and nozzle pressures: *a*, 50-foot length of 2½-inch unlined hose, 1-inch smooth-bore nozzle; *b*, 50-foot length of 1½-inch unlined hose, ⅝-inch smooth-bore nozzle

Friction-loss tests were made as follows: Piezometers (1½-inch) were connected to the inlet and discharge ends of the hose, and the drop in pressure over the hose for various rates of flow was read on a differential mercury gauge. The top of one tube of this gauge was connected to the intake piezometer and the top of the other to the discharge piezometer. By this method the difference of pressure between two ends of the hose was indicated accurately by the column of mercury. The discharge piezometer was connected to a 2½-inch line terminating in a meter nozzle by which the flow or discharge in gallons per minute was obtained.

HIGH-PRESSURE REGULATING DEVICES

In metal mines where the water column may be high and the resulting head great, a means of automatically reducing the pressure so that it will be controllable at the nozzle may be required.

A number of regulating valves are on the market. Nearly all of them, however, rely on the proper action of moving parts which may not function at a critical time, and hence they hardly appear suitable for places where they may be operated only at long intervals and where they may receive little or no care.

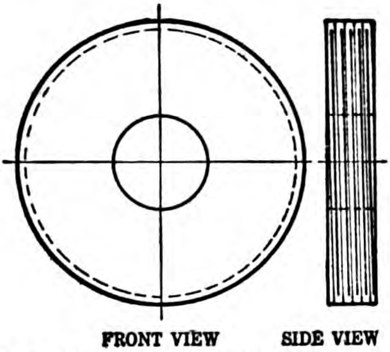


FIGURE 6.—Disk used to reduce water pressure in fire lines

One of the most successful means for reducing the pressure is exceedingly simple. It is a disk (Figs. 6 and 7) threaded on the outside edge so that it can be screwed into the fire line close to the connection with the main water line. In the center of this disk an orifice restricts the flow of water and thus reduces the pressure on the line supplying the valve to which the fire hose is attached. The reader should note, however, that this disk does not reduce the pressure when the column of water is at rest. If the head of the water in the main water line is very high the resulting pressure will be transmitted to the fire line. Therefore, unless the fire line is made of pipe that can withstand the pressure due to the static head, no valve should be placed on it. On the other hand, if the fire line is long, valuable time may be lost by a man traveling any great distance to the controlling valve.

When an underground water supply for fighting fires is planned, these two points must be considered.

EFFECT OF DISK ON NOZZLE PRESSURE

This disk has been tested to a pressure as high as 160 pounds per square inch, which it has reduced to 60 pounds per square inch.

Where water from a high-pressure line is carried in pipes along the levels in a mine for considerable distances to the hose-line connections, the friction will affect the nozzle pressure; if the service pressure is reduced from 160 pounds to 60 pounds by the disk, the nozzle pressure will be less than 60 pounds, the loss varying with the size of the pipe and the distance the water has to travel.

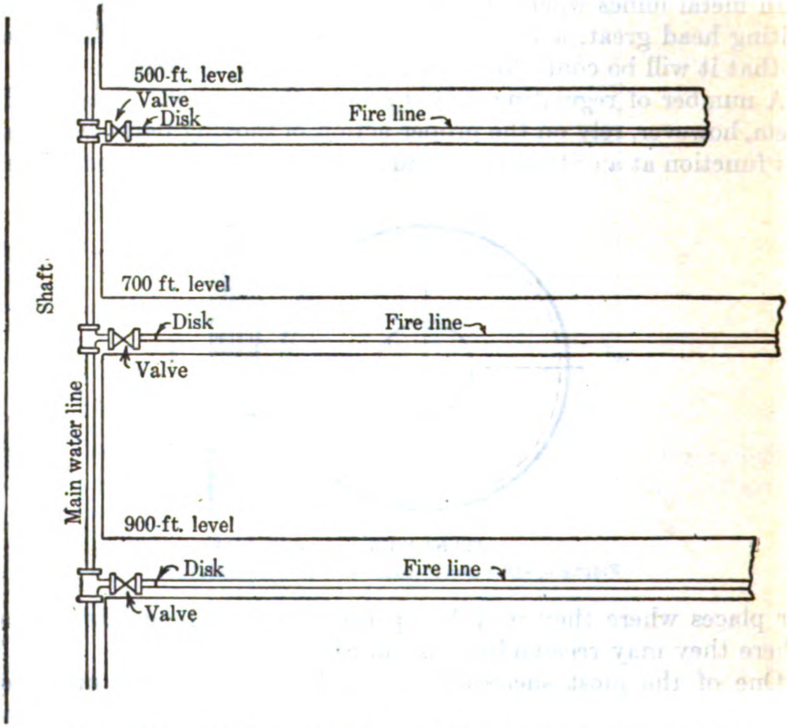


FIGURE 7.—Diagram showing application of disk in fire lines at different levels of a mine

Table 5 shows the pressure reduction due to the insertion of a brass disk for different lengths of unlined linen hose with different sizes of nozzles.

TABLE 5.—*Effect of disk on nozzle pressures for different lengths and sizes of hose and nozzles*

50 feet 1½-inch unlined linen hose; five-eighths-inch smooth-bore nozzle

Diameter of restriction-disk orifice, inch	Service pressure, pounds per square inch	Nozzle pressure, pounds per square inch
40/64 (5/8)	152	50. 0
45/64	147	60. 0
46/64 (23/32)	140	60. 0
48/64 (3/4)	131	60. 0
48/64 (3/4)	131	60. 0
51/64	123	60. 0
53/64	113	60. 0
56/64 (7/8)	110	60. 0
59/64	104	60. 0
62/64 (31/32)	103	60. 0
3/4	168	77. 5
Without disk	89	60. 0

100 feet 1½-inch unlined linen hose; five-eighths-inch smooth-bore nozzle

Diameter of restriction-disk orifice, inch	Service pressure, pounds per square inch	Nozzle pressure, pounds per square inch
48/64 (3/4)	159	60
48/64 (3/4)	160	60
50/64 (25/32)	154	60
52/64 (13/16)	147	60
54/64 (27/32)	142	60
56/64 (7/8)	137	60
59/64	134	60
62/64 (31/32)	131	60
Without disk	117	60

50 feet 2½-inch unlined linen hose; 1-inch smooth-bore nozzle

Diameter of restriction-disk orifice, inch	Service pressure, pounds per square inch	Nozzle pressure, pounds per square inch
63/64	161	45
1⅛	149	60
1¼	119	60
1⅜	105	60
1½	93	60
1⅝	87	60
1¾	82	60
Without disk	75	60

75 feet, 2½-inch unlined linen hose; 1-inch smooth-bore nozzle

Diameter of restriction-disk orifice, inch	Service pressure, pounds per square inch	Nozzle pressure, pounds per square inch
1⅛	132	50
1⅛	156	60
1¼	126	60
1⅜	112	60
1½	101	60
1⅝	95	60
1¾	90	60
1⅞	86	60
Without disk	83	60

TABLE 5.—*Effect of disk on nozzle pressures for different lengths and sizes of hose and nozzles*—Continued

100 feet 2½-inch unlined linen hose; 1-inch smooth-bore nozzle

Diameter of restriction-disk orifice, inch	Service pressure, pounds per square inch	Nozzle pressure, pounds per square inch
1⅛	148	53
1¼	136	60
1⅜	119	60
1½	110	60
1⅝	104	60
1¾	98	60
1⅞	96	60
2	96	60
Without disk	92	60

The above data are given merely to show the possibilities of the use of this disk at the higher pressures.

DETERIORATION OF FIRE HOSE

An interesting point is the ability of different types of fire hose to resist deterioration under mine conditions, especially where the mine water is sulphur bearing.

According to the records of the Underwriters' Laboratories, rubber-covered cotton rubber-lined hose seems likely to give better service in mines where the hose is liable to be subjected to contact with sulphur compounds. Ordinary cotton rubber-lined hose deteriorates rapidly when its exterior comes in contact with weak solutions of sulphuric acid.

It is recommended that all fire hose bear the inspection label of the Underwriters' Laboratories.

STANDARD HOSE COUPLINGS

As many mining communities depend upon the equipment at the mines for protection of houses, stores, public halls, and other property against fire, and as one or more communities must sometimes help a neighboring one to fight fire, discussion of a standard type of interchangeable equipment is not out of place.

There are at present about nine so-called standards for small hose-coupling threads. Table 6, taken from the report of the National Fire Protection Association's committee on small hose couplings under date of May, 1920, shows the extremes in variation in pitch and diameter of these standards.

TABLE 6.—*Difference in so-called standards for coupling threads for small hose*

Size of coupling	Pitch of thread	Outside diameter of male thread	
		Range	Difference
Inches	*Threads per inch*	*Inches*	*Inches*
½	11 to 14	1.046 to 1.08	0.034
¾	11 to 14	1.046 to 1.26	.214
1	11 to 11½	1.30 to 1.44	.14
1¼	10 to 11½	1.63 to 2.10	.47
1½	10 to 11½	1.88 to 2.14	.26
2	7 to 11½	2.35 to 2.78	.43

If the officials of one mine should ask help from another, and the hose of the first mine should have couplings with 10 threads to the inch and an outside diameter of 2.10 inches, whereas couplings for the same size hose of the second mine should have 11½ threads to the inch with an outside diameter of 1.88 inches, the confusion that would result can readily be imagined.

One of the most notable examples of such trouble is the Baltimore fire in 1904, when many fire departments from other cities were unable to connect up with the Baltimore department's equipment, because of differing standards of threads. Consequently what would have been valuable aid proved of little or no avail.

As a consequence of this lack of standardization the National Fire Protection Association has compiled "Specifications for Standard Threads for Hose Couplings." The specifications covering couplings 2½ to 4½ inches in size have come to be known as "National Standard," and are indorsed by several national organizations, the principal American engineering societies, and water works and fire chiefs' associations. The standard for threads for couplings of the smaller sizes, to 2½ inches, inclusive, which were developed later than the National Standard for the larger sizes, has thus far been indorsed by the following organizations:

National Fire Protective Association.

National Board of Fire Underwriters.

Associated Factory Mutual Fire Insurance Companies.

Manufacturers' Committee on Standardization of Fittings and Valves.

Figure 8 shows the dimensions specified in the above standards for ½-inch to 4½-inch couplings.

One great advantage of the standards developed by the National Fire Protection Association's committee is the facility with which a large percentage of the threads of the 2½-inch couplings now in service may be resized and standardized. Special thread-cutting tools have been designed with which any mechanic who has ordinary knowledge of thread cutting and hydrants, hose couplings, and engine connections can easily and quickly change threads to conform to the national standard.

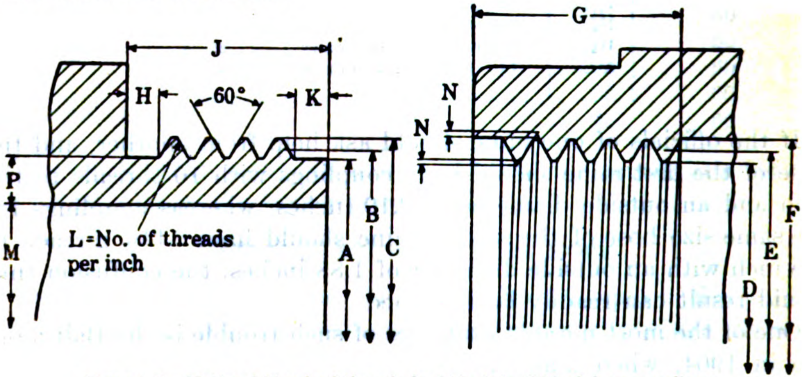


FIGURE 8.—National Standard threads for ½-inch to 4½-inch hose couplings

Size	A R. D.	B P. D.	C O. D.	D I. D.	E P. D.	F R. D.	G	H	J	K	L	M	N	P
½	0. 9419	1. 0022	1. 0625	0. 9619	1. 0222	1. 0825	31/64	⅛	39/64	1/16	11½	23/32	0. 0075	7/64
¾	. 9419	1. 0022	1. 0625	. 9619	1. 0222	1. 0825	31/64	⅛	39/64	1/16	11½	23/32	. 0075	7/64
1	1. 1874	1. 2477	1. 3080	1. 2074	1. 2677	1. 3280	31/64	⅛	39/64	1/16	11½	1	. 0075	7/64
1¼	1. 5246	1. 6008	1. 6770	1. 5496	1. 6258	1. 7020	43/64	⅛	51/64	⅛	9	1¼	. 0100	9/64
1½	1. 8376	1. 9138	1. 9900	1. 8626	1. 9388	2. 0150	43/64	⅛	51/64	⅛	9	1½	. 0100	11/64
2	2. 3435	2. 4317	2. 5200	2. 3685	2. 4567	2. 5450	13/16	⅛	15/16	3/16	8	2	. 0100	11/64
2½	2. 8716	2. 9670	3. 0625	2. 9016	2. 9970	3. 0925	⅞	⅛	1	¼	7½	2½	. 0100	3/16
3	3. 3763	3. 5007	3. 6250	3. 4063	3. 5307	3. 6550	1	⅛	1⅛	¼	6	3	. 0100	3/16
3½	4. 0013	4. 1257	4. 2500	4. 0313	4. 1557	4. 2800	1	⅛	1⅛	¼	6	3½	. 0100	¼
4½	[a]5. 3570	5. 5535	5. 7500	5. 4070	5. 6035	5. 8000	1¼	⅛	1⅜	¼	4	4½	. 0100	21/64

[a] Report on National standard threads for hose couplings calls for 5.397 0 inches R. D. of male thread.

Additional information concerning these special tools may be obtained from the National Board of Fire Underwriters, 76 William Street, New York, N. Y., and the Underwriters' Laboratories, 207 East Ohio Street, Chicago, Ill.

All mining companies about to purchase fire-fighting equipment should carefully consider the adoption of these standard thread specifications.

CONCLUSIONS

The most effective combination of fire hose and water pressure for one man fighting a mine fire is that which gives a stream with maximum trajectory in a limited headroom and delivers the greatest volume of water, but it also must be of such weight and flexibility that a man of ordinary weight and strength can advance or retreat with the hose while playing it on the fire; it must not give a reaction that will wrench the nozzle from the operator's control when the water is suddenly turned on at the supply valve; it must not cause vibration that will numb the muscles of the operator or exhaust his strength within a reasonable length of time; and it must be such that the hose if accidentally dropped can be recovered without chance of injury to the operator.

The figures in Table 7, taken from the curves shown in Figure 9, compare the flow from two sizes of hose at different pressures. The data for the curves in Figure 9 are taken from the results of the tests conducted in the Underwriters' Laboratories at Chicago.

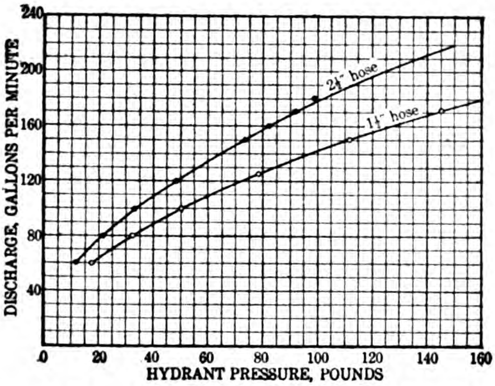


Figure 9.—Curves showing discharge at different hydrant pressures through 50 feet of cotton rubber-lined hose with three-fourths-inch smooth-bore nozzle

Table 7.—*Discharge from $^3/_4$-inch nozzle on $1^1/_2$ and $2^1/_2$ inch hose at different pressures*

Hydrant pressure, pounds	1½-inch hose, gallons per minute	2½-inch hose, gallons per minute
30	78	96
35	84	102
40	89	110
45	94	118
50	100	124
55	104	130
60	108	136
65	114	142
70	118	148
75	122	153
80	127	158
85	130	164
90	134	169
95	137	174
100	140	179

Table 7 shows that the 1½-inch hose is about 80 per cent as efficient as the 2½-inch hose when only the quantity of water delivered in a given time is considered. Also, a greater trajectory can be obtained with the larger hose (see p. 12). However, in the opinion of those who witnessed the tests, these advantages are more than offset by the stiffness and additional weight which make the larger hose more difficult to handle.

Therefore, it is believed that a 1½-inch line is more effective when the attacking of a mine fire is to be done primarily by one man. When, however, a well-organized fire-fighting force is at hand and when men can easily be relieved after a short time a 2½-inch hose may be advantageous.

MOST EFFICIENT PRESSURE AND SIZE OF NOZZLE

Table 4 (p. 11) shows that at a hydrant pressure much above 45 pounds the stream breaks to pieces; that is to say, the larger part of the water is about evenly distributed over the distance O–P in Figure 1, on p. 10. Therefore, hydrant pressures around 45 pounds are judged to be most efficient for a 50-foot line of 1½-inch hose.

As to the most efficient size of nozzle and the most suitable pressure to be used, much depends on the nature of the fire. If the fire should be in a place where the headroom is ample, the roof and walls incombustible, and the flames feeding on timber and supplies, the most effective-sized nozzle, it would seem, would be the one giving the greatest volume of water and the greatest trajectory.

Inspection of Table 4 seems to show that this requirement would be met by a three-fourths inch nozzle at a pressure of about 45 pounds per square inch and a delivery of 96 gallons per minute, with a trajectory of about 72 feet.

There is, however, a fire condition which requires a somewhat different attack. This would be found in a narrow entry with a roof which would burn readily, while the floor would perhaps be more or less incombustible. Such a condition can be typified in an entry in a coal mine with perhaps 5 or 6 feet headroom and a bony coal roof. In such an entry a stream of water that breaks up has been found by engineers of the bureau to be an advantage, in that it gives a better distribution of the water on the fire area, and the fire which the innermost end of the trajectory reaches is usually the material which has fallen from the ribs or roof and is burning on the floor of the mine.

A long trajectory is an advantage in extinguishing such a fire. That part of the fire which is, perhaps, most dangerous and troublesome—that in the roof—can only be reached by the highest point of the trajectory, the point whose distance from the nozzle is indicated by N in Figure 2. For fighting fires in the average coal mine, this is really the most effective part of the water trajectory as it puts the water near the roof and any excess water cascades to the bottom, and thus does double duty by quenching fire in the roof and on the ribs.

This requirement would also be met by a three-fourths inch nozzle at a pressure of about 45 pounds per square inch and a delivery of 96 gallons per minute, with a trajectory of about 72 feet.

SUMMARY

A 2½-inch hose is too heavy and too hard to handle; with a three-fourths-inch nozzle the volume of water it delivers at the lower pressure is not enough larger than that which a 1½-inch hose delivers through the same size nozzle to overcome the disadvantage of extra weight.

The maximum hydrant pressure that produces the most effective stream through 50 feet of cotton rubber-lined hose is around 45 pounds per square inch. At much higher pressure the body of the stream is shattered.

The data obtained show that the three-fourths-inch nozzle apparently gives the most efficient stream with 50 feet of 1½-inch cotton rubber-lined hose. It must be remembered, however, that as the distance of the nozzle from the hydrant increases the nozzle pressure decreases, owing to the friction of the water against the inside of the hose; therefore the hydrant pressure should be increased as the length of the hose line is increased. Possibly a more extensive investigation with nozzles of different designs and workmanship might indicate that other sizes are more efficient.

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